Lateral Instability in Nanoimprinted Polymer Structures

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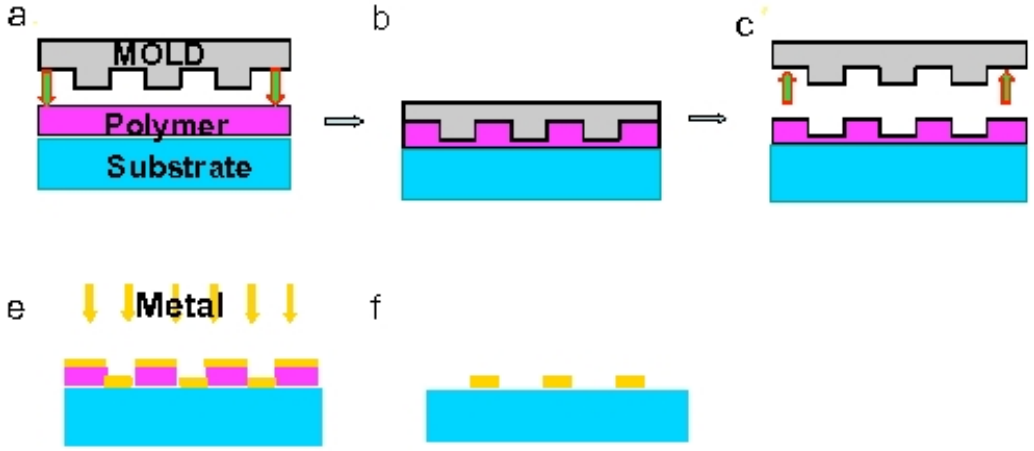
Nanoimprint Lithography(NIL)

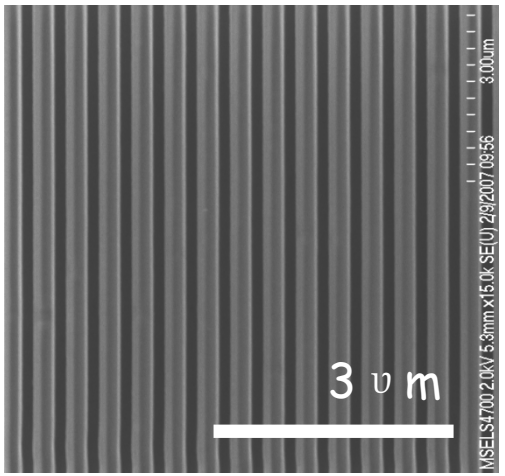
- Nanoscale pattern (metals, semiconductors…)
- Advantages: low cost, high throughput and high resolution (below 10nm)
- Challenges:

  mold release

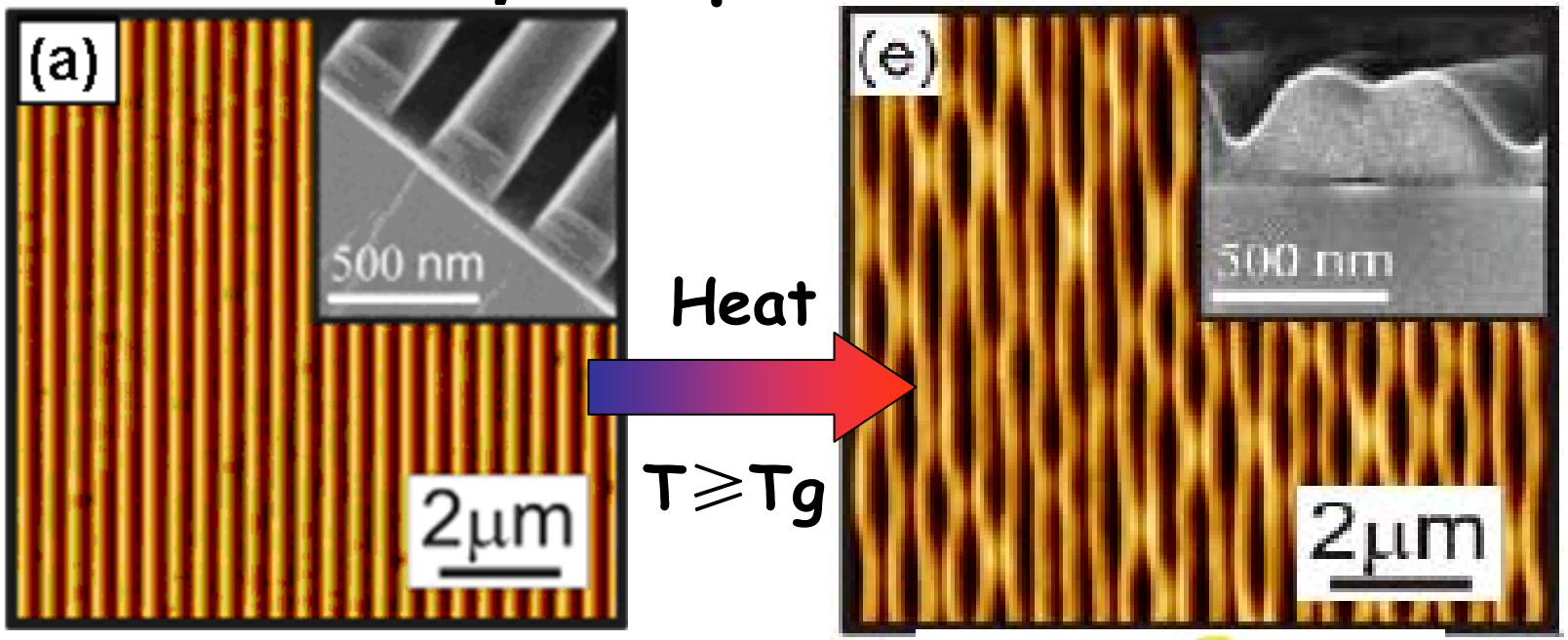
  thermal stability of the polymer pattern

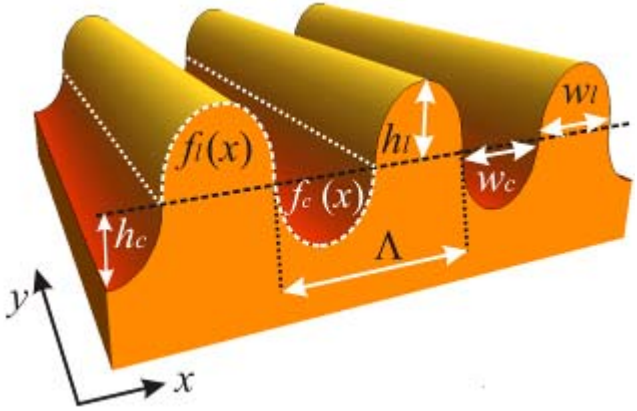


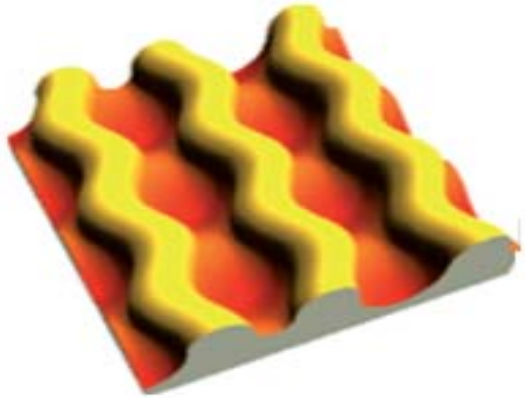
Christine Chin, The Journal of Young Investigators 16.5 (2007)



Development of the zigzag instability in polymer pattern







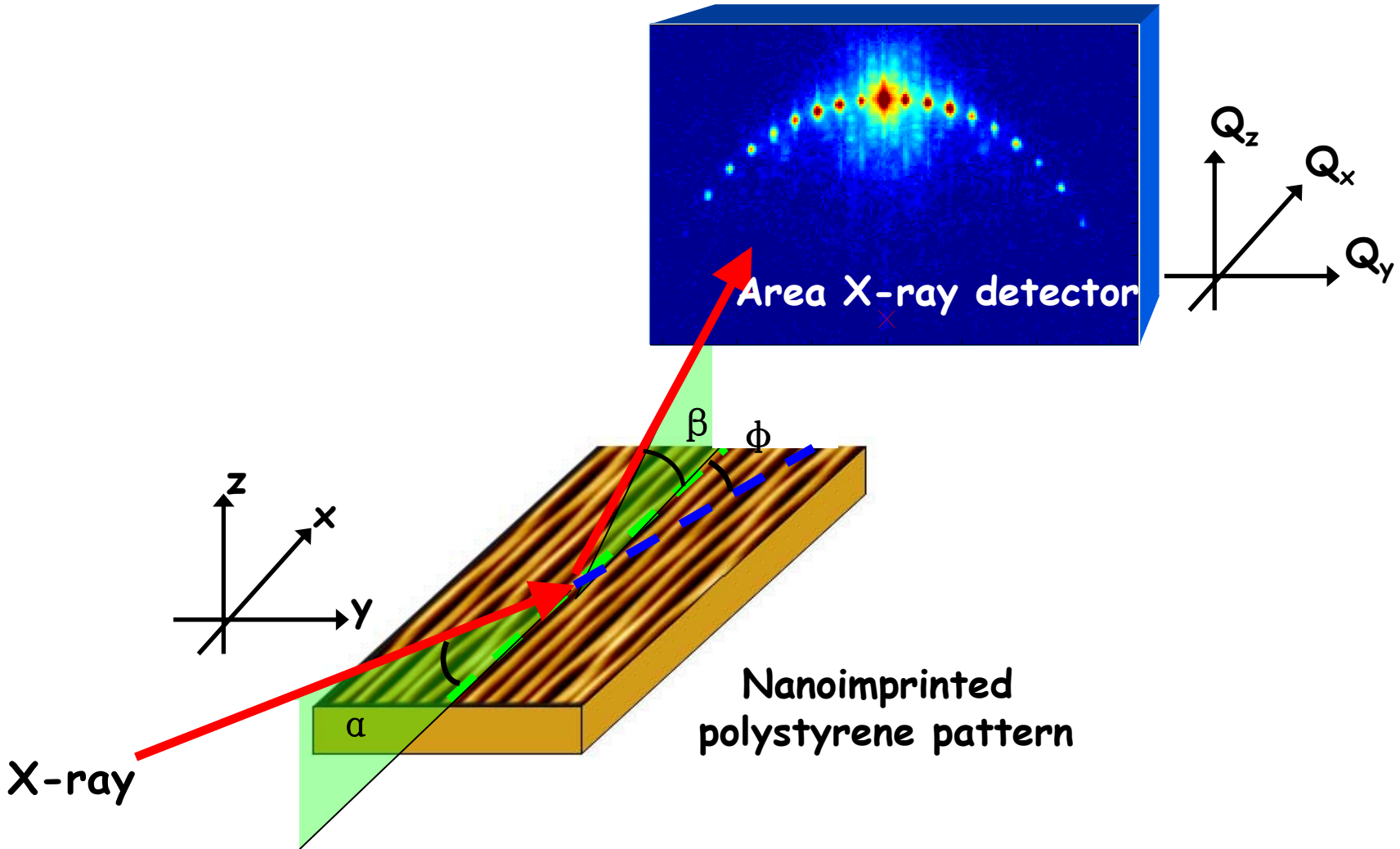
Kyle Alvine, Chris Soles et al., Soft Matter, 2009, 5, 2913–2918

AFM vs. GISAXS

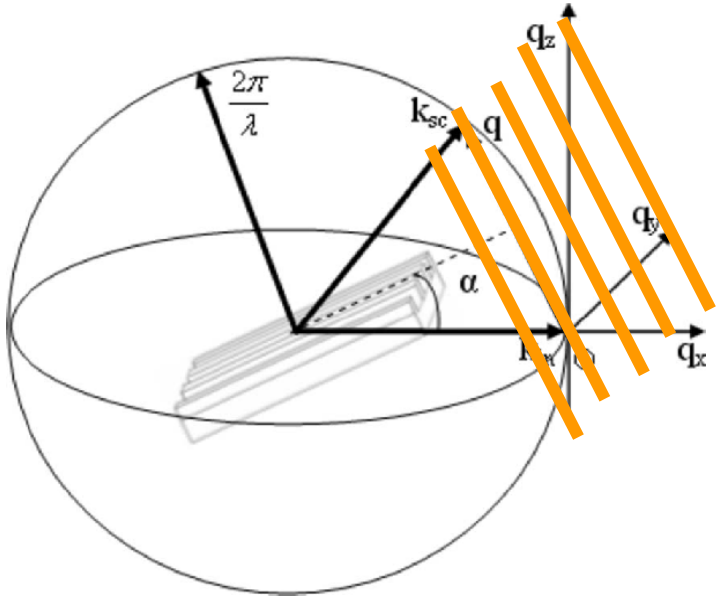
Time-resolved Grazing-Incidence Small-Angle X-ray Scattering

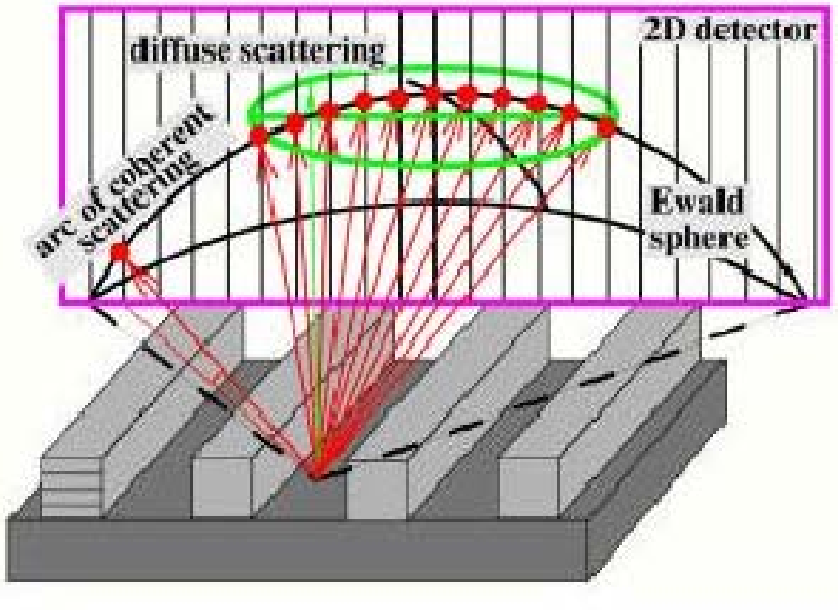
	pros	cons
Local Probe In-situ AFM	time resolved High resolution, real space, 3D	temporal resolution (10~100s) (or field of view) May disrupt the sample, Drift
GISAXS **Global Probe**	high time resolution (10 ms -100 s) Global average of sample	Quantitative results can only be achieved by the application of a suitable model

Experiment setup at APS sector 8

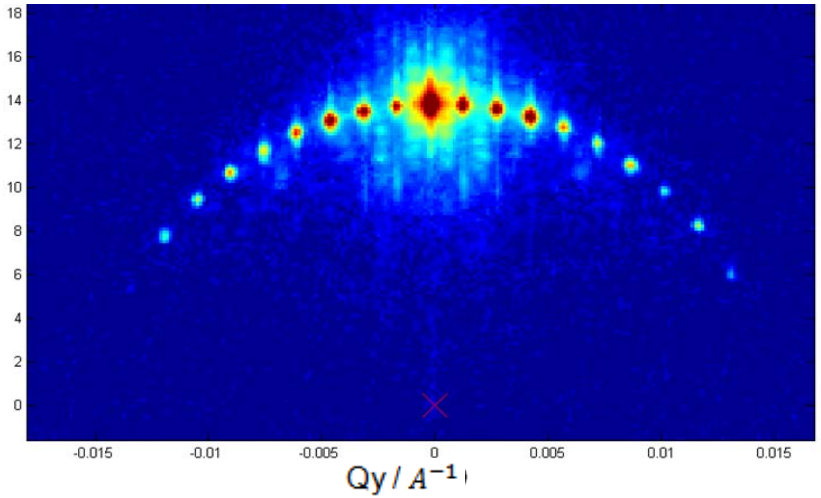


Diffraction Pattern Geometry

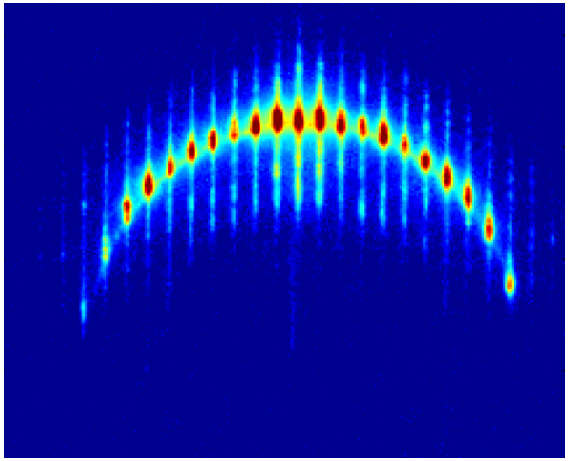




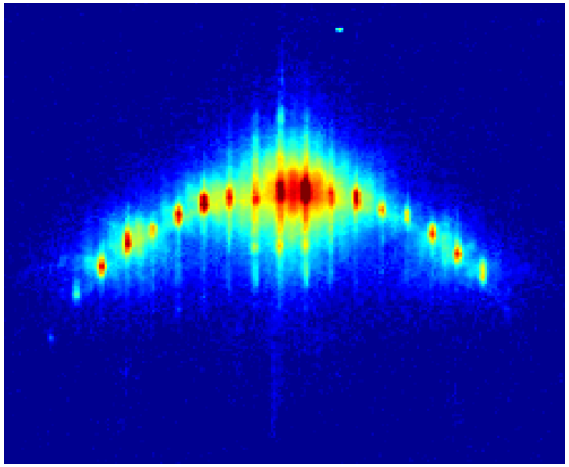
Schematic representation of the Ewald sphere and of the reciprocal space.



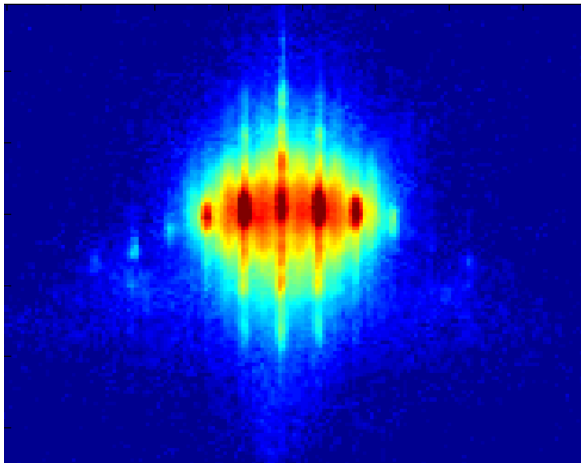
Thermal Decay of Nanoimprinted Patterns



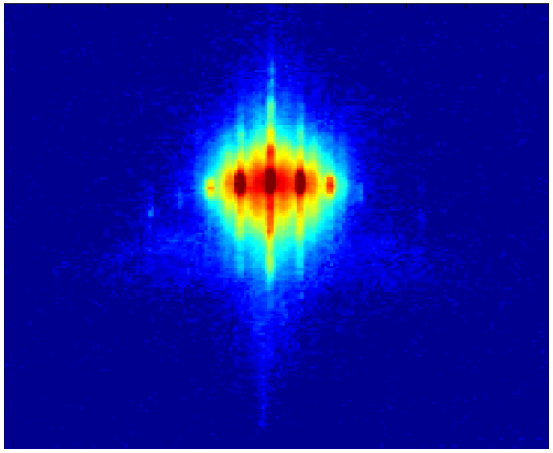
M1A#2 @ Tg+20 ⇨



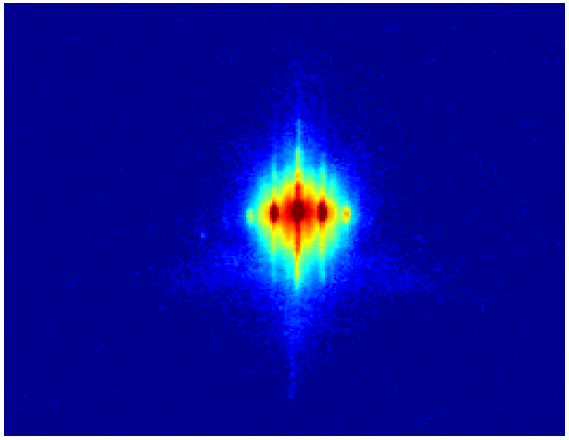
~ 2 min



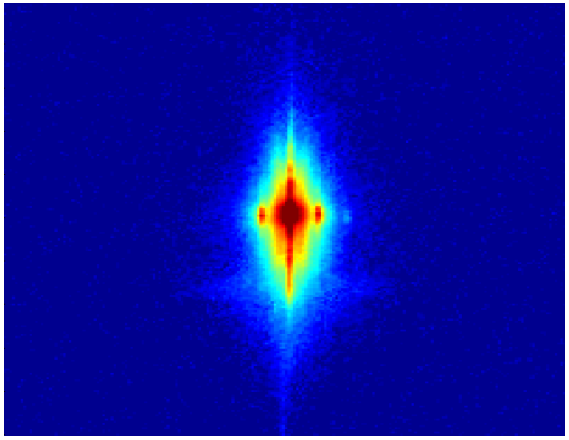
~ 3.5 min



~ 7.5 min

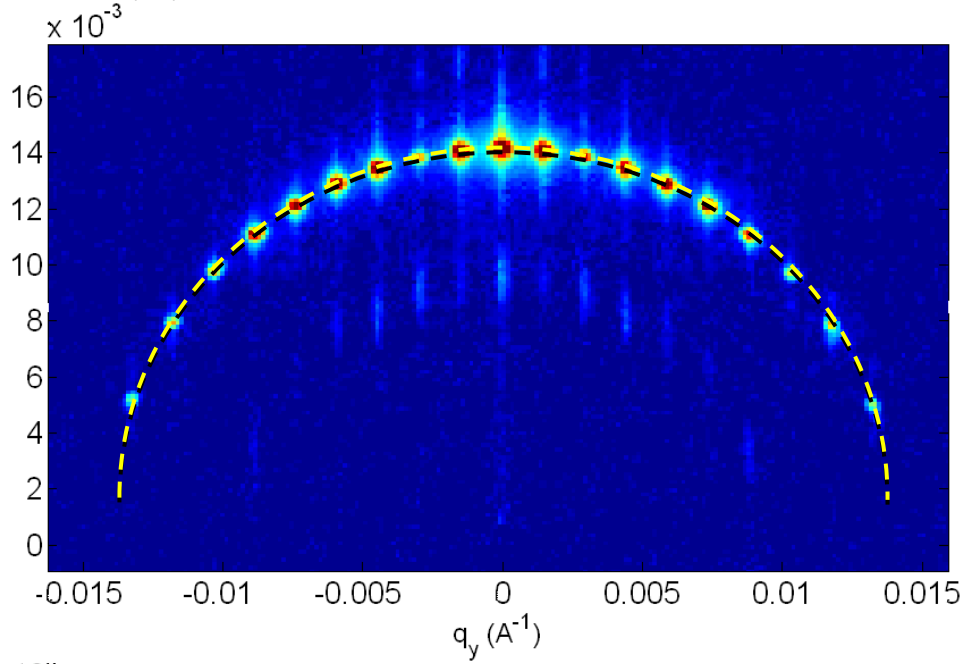


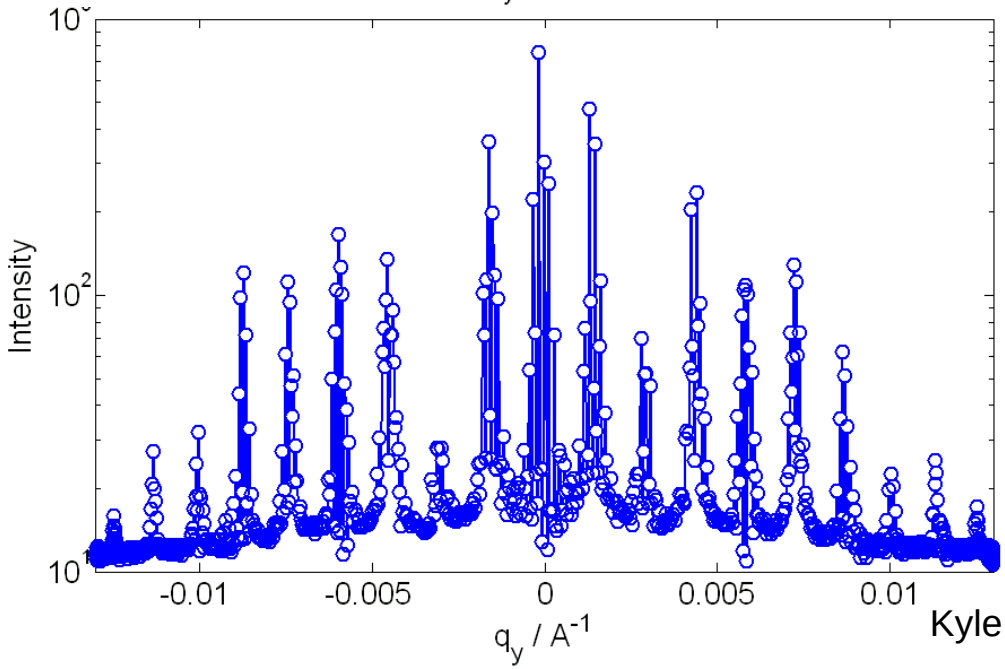
~ 11 min

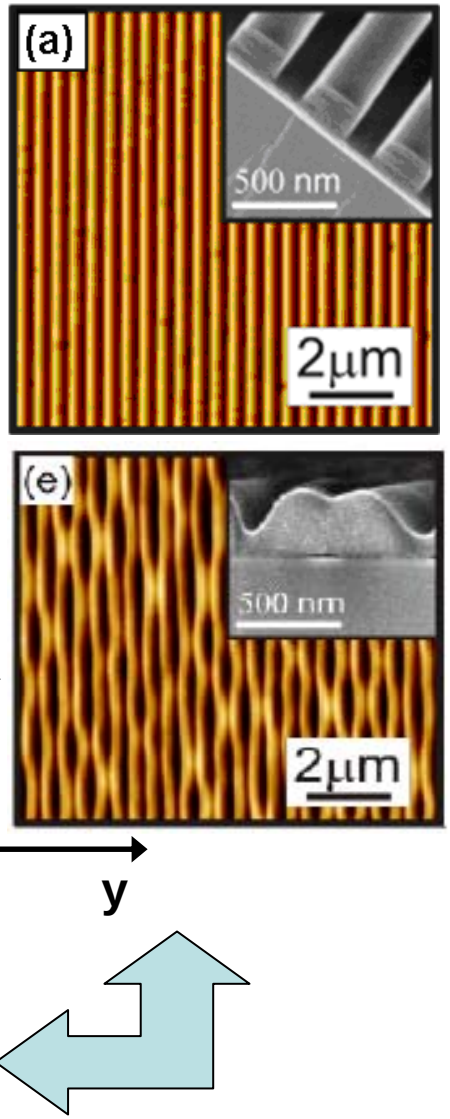


~ 30.5 min

From Diffraction intensities to real-space







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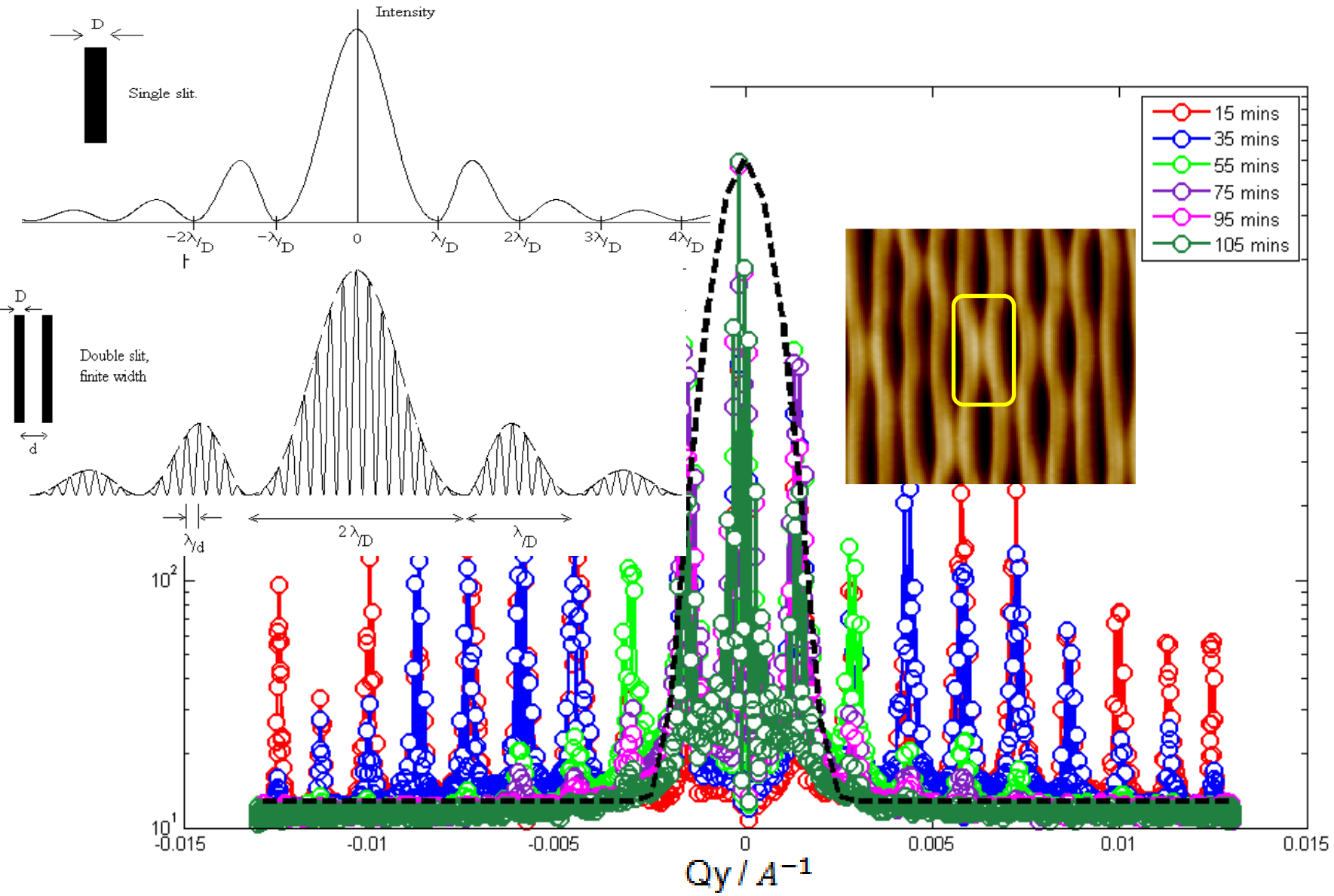
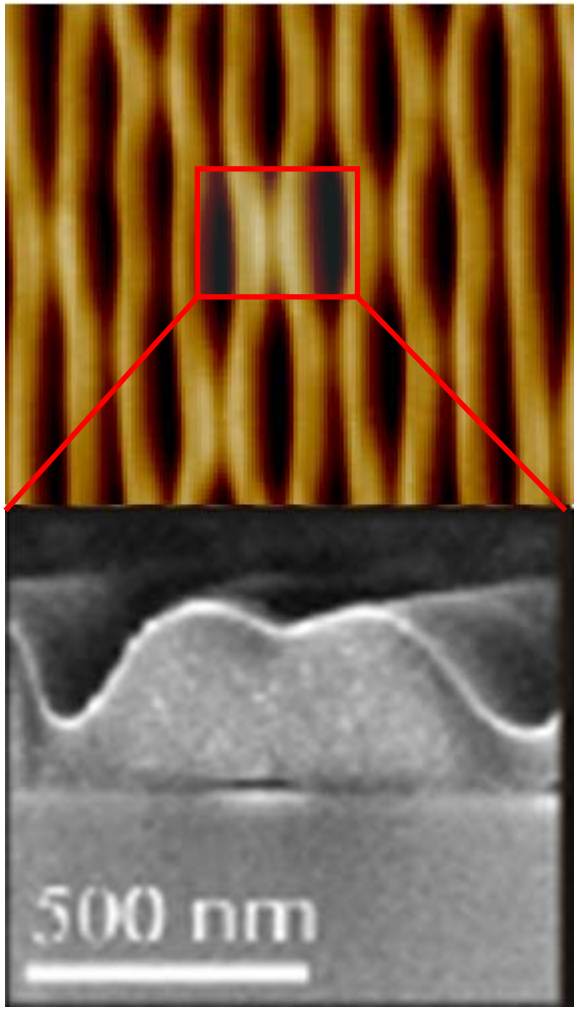
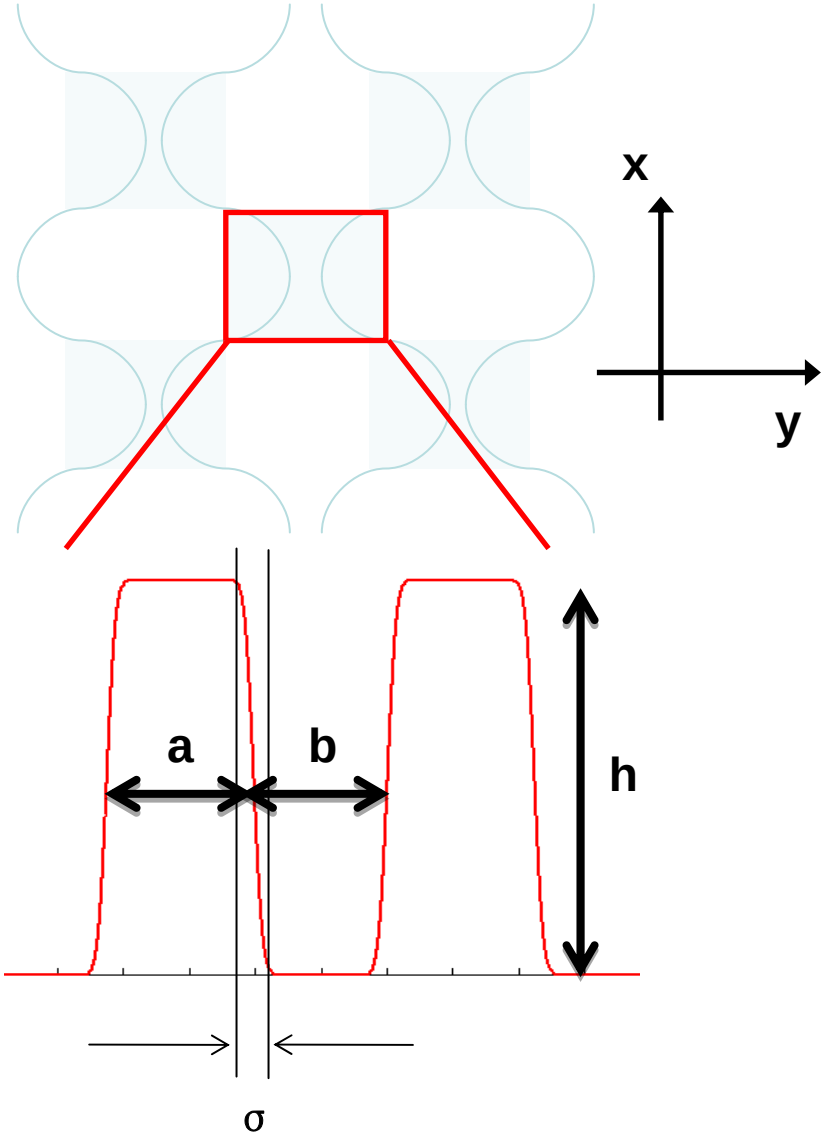
Analysis of the Form Factor based on Zigzag Unit Cell Model



Zigzag unit cell and Two-lines model

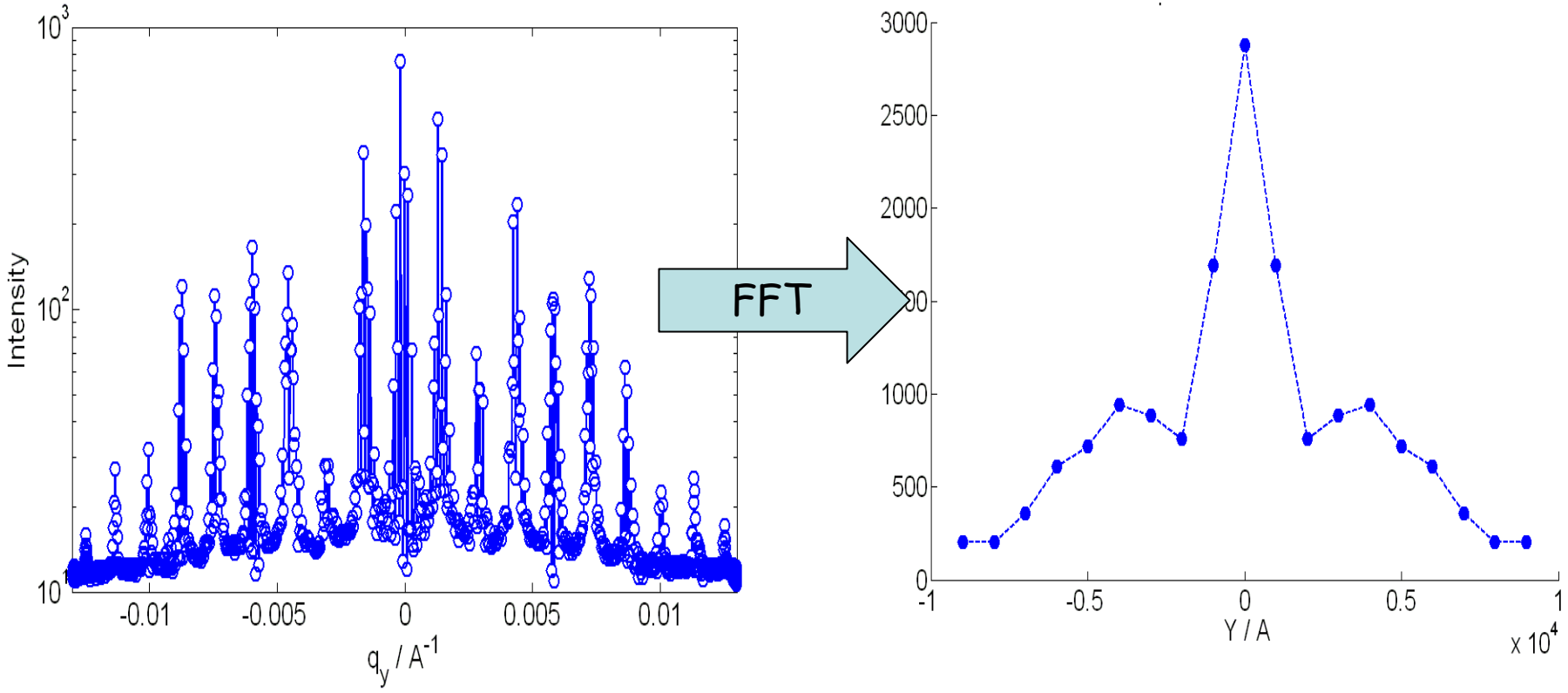




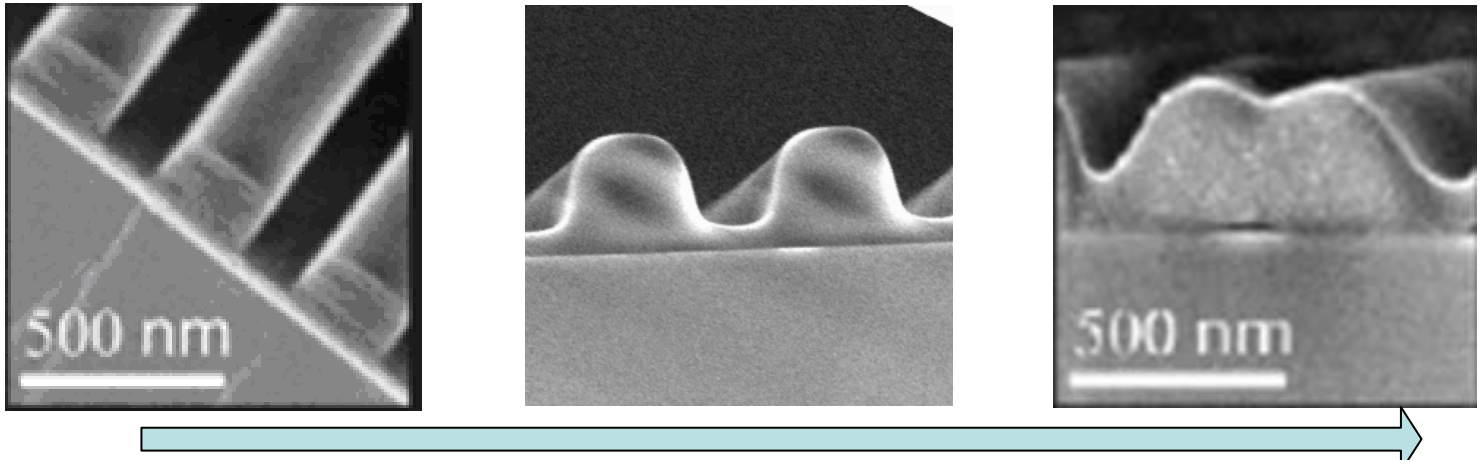
Patterson Function

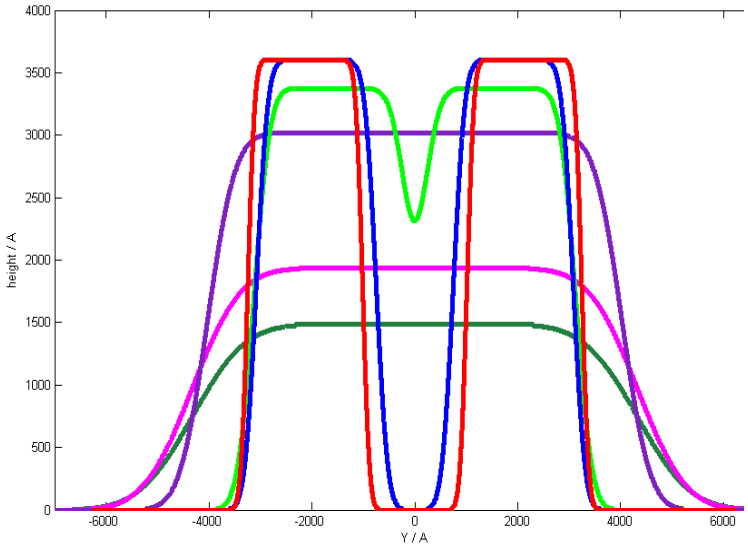
equivalent to the structure profile convolved with its inverse:

$$P(y)=FFT(I(qy))=H(y)\otimes H(-y)$$



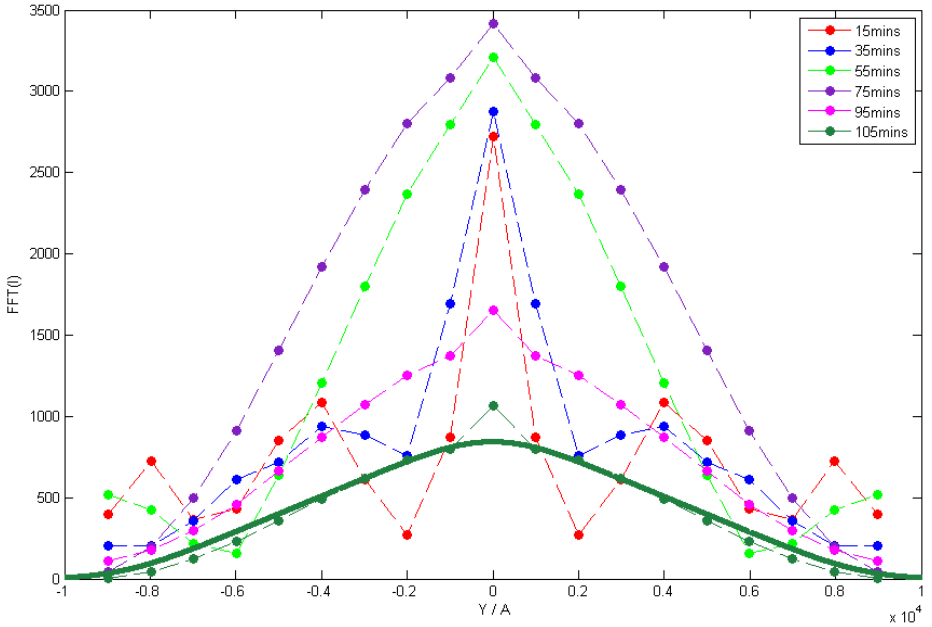
Evolution of Lateral Structure



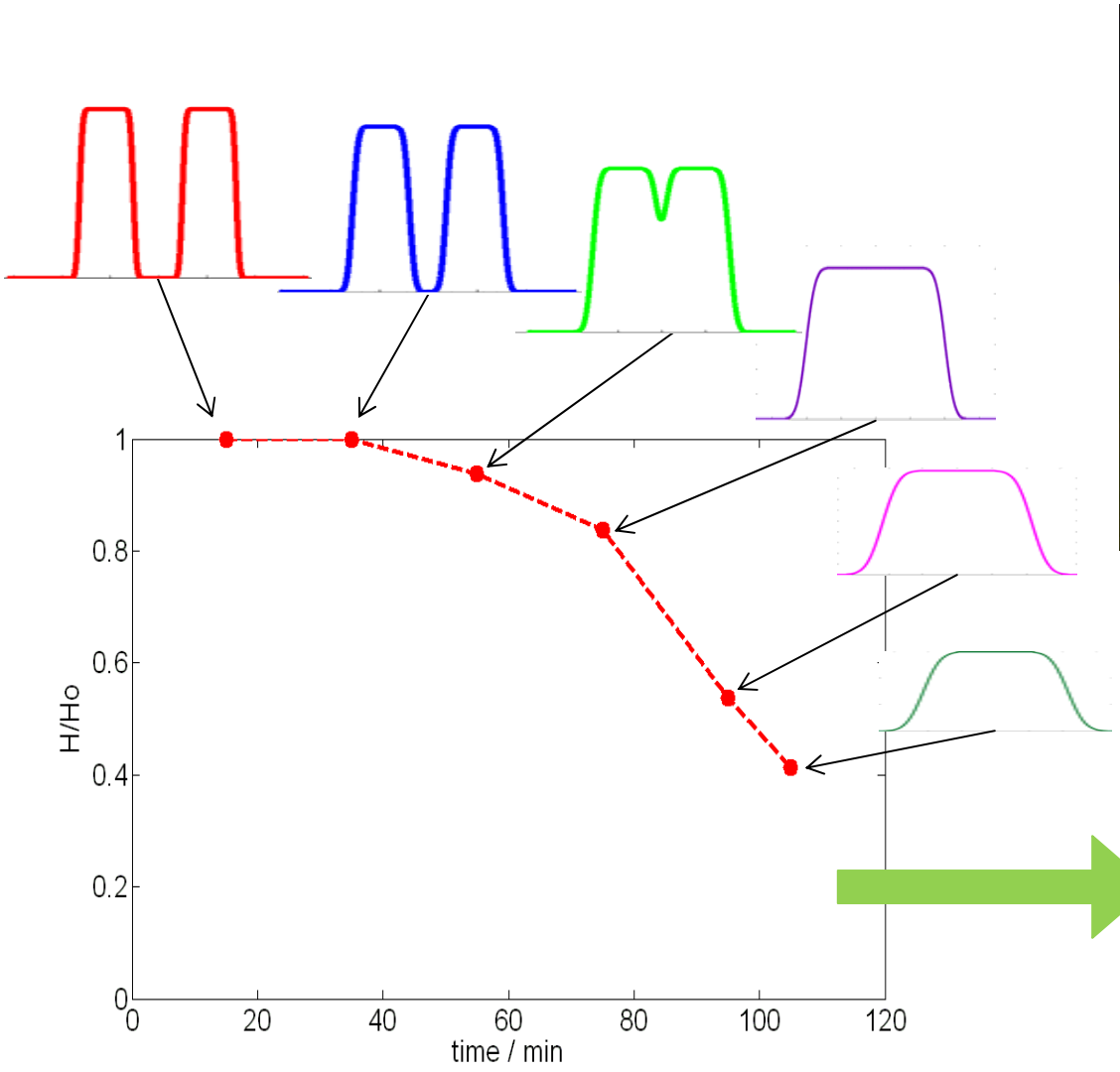


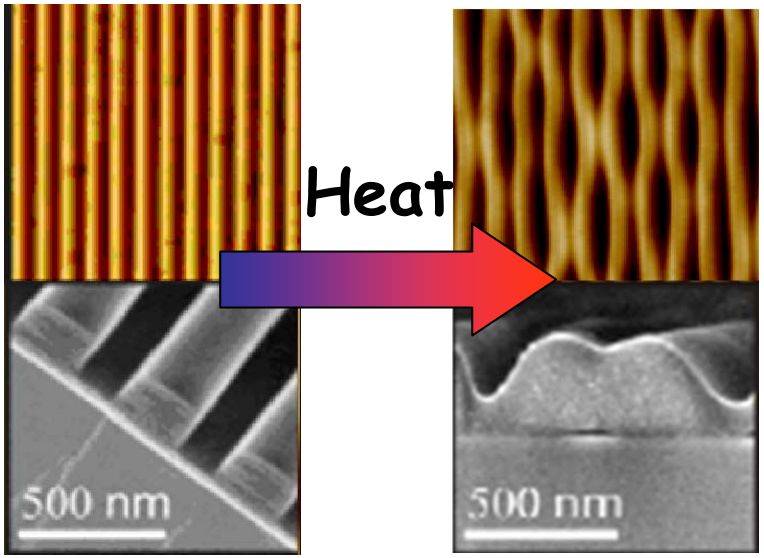
Lateral structure

Patterson function



Thermal instability
→ surface energy reduction





Will continue with exponential height decay to lower surface energy

Summary

- GISAXS gives us time resolved, almost instant, high-resolution profile of coalescence unit cell.
- Complimentary information is confirmed by local probe, such as AFM.
- Both technique shows that the instability proceeds through zig-zag undulation /coalescence of lines first, followed by pattern height decay to flat film later.

Collaboration:

- Yeling Dai, Oleg Shpyrko
  (University of California, San Diego)
- Hyun Wook Ro, Christopher Soles
  (National Institute of Standards and Technology)
- Kyle Alvine (Pacific Northwest National Lab)
- Joe Strzalka, Alec Sandy (Argonne National Lab)

Thanks!

Questions?